U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.4 POTENTIAL DAM FAILURES

REVIEW RESPONSIBILITIES

Primary - Hydrologic and Geotechnical Engineering Branch (HGEB)

Secondary - None

I. AREAS OF REVIEW

In this section of the safety analysis report (SAR) the hydrogeologic design basis is developed to assure consideration in plant design of any potential hazard to the safety-related facilities due to the failure of upstream and downstream water control structures. The areas of review include consideration of flood waves (bores) from severe breaching of upstream dams and the potential loss of water supply due to failure of a downstream dam, domino-type failures of dams, landslides, and effects of sediment deposition and erosion.

When data are provided to show that seismic events will not cause failures of upstream dams that could produce the governing flood at the plant, this section may contain additional data and other information to support a contention that the dams are equivalent to seismic Category I structures and will survive a local equivalent of the safe shutdown earthquake (SSE) or will survive the operating basis earthquake (OBE). In such cases the Geotechnical Engineering Section (GES) of HGEB, the Geosciences Branch (GB), and Structural Engineering Branch (SEB), as necessary, will evaluate the data necessary to justify such a classification. GES, GB, and SEB review procedures are outlined in the appropriate geosciences and structural SRP sections. The balance of this SRP section applies to the hydrologic analyses of dam failures or breaches.

Where analyses are provided in support of either a conclusion that a probable maximum flood (PMF) should be the design basis flood for a stream, or that a postulated or arbitrarily assumed dam failure flood is the design basis flood for a stream, the areas of review consist of the following:

1. Conservatism of modes of assumed dam failure and deposition of debris downstream.

2. Consideration of flood control reservoirs at full pool level.

3. Conservatism of coincident flow rates and levels depending on whether failure is postulated with an equivalent SSE coincident with a 25-year flood, or an OBE coincident with a standard project flood (SPF). An SPF is considered to be about forty percent of a PMF.

4. Flood wave attenuation to downstream dams, or to the site, whichever would be encountered first.

5. Potential for mutiple dam failures; flood wave effects and potential for failure of downstream dams.

6. Hydraulic failure as a result of overtopping for any reason.

7. Dynamic effects of possible bores on exposed plant facilities.

8. Conservative flow conditions for downstream dam failures that can influence safety-related water supplies.

9. Applicability and conservatism of models used to predict the effects of dam failure floods including breach shape and rate of failure.

II. ACCEPTANCE CRITERIA

Acceptance criteria for this SRP section are based on meeting the requirements of the following regulations:

1. General Design Criterion 2 (GDC 2) as it relates to structures, systems and components important to safety being designed to withstand floods.

2. 10 CFR Part 100 as it relates to evaluating hydrologic features of the site.

3. 10 CFR Part 100, Appendix A as it relates to establishing the design basis flood due to seismic dam failure.

To meet the requirements of GDC 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A, as they relate to dam failures, the following specific criteria are used:

The staff will review the applicant's analyses and independently assess the coincident river flows at the site and at the dams being analyzed. ANSI N170 provides guidance on acceptable river flow conditions to be assumed coincident with the dam failure event. The applicant's estimates (which may include landslide-induced failures) of the flood discharge resulting from the coincident events should be no more than 5% less conservative than the staff's estimates to be acceptable. If the applicant's estimates differ by more than 5%, the applicant should fully document and justify its estimates or accept the staff's estimates and redesign applicable flood protection.

For SAR Section 2.4.4.1 (Dam Failure Permutations): The location of dams and potentially "likely" or severe modes of failure must be identified. The potential for multiple, seismically-induced dam failures and the domino failure of a series of dams must be discussed. Approved models of the Corps of Engineers and the Tennessee Valley Authority are used to predict the downstream water levels resulting from a dam breach (Refs. 7, 11, 16, 17 and 18). First-time

use of other models will require complete model description and documentation. Acceptance of the model (and subsequent analyses) is based on the staff review of model theory, available verification, and application. Where other than instantaneous failure is assumed, the conservatism of the rate of failure and shape of the breach should be well documented. A determination of the peak flow rate and water level at the site for the worst possible combination of dam failures and a summary analysis (that substantiates the condition as the critical permutation) must be presented, along with a description (and the bases) of all coefficients and methods used. Also, the effects of other concurrent events on plant safety, such as blockage of the river and water-borne missiles, must be considered.

For SAR Sections 2.4.4.2 (Unsteady Flow Analysis of Potential Dam Failures) and 2.4.4.3 (Water Level at Plant Site): The effects of coincident and antecedent flood flows (or low flows for downstream structures) on initial pool levels must be considered. Use of the methods given in References 4 or 6 is acceptable for determination of initial pool levels. Depending upon estimated failure modes and the elevation difference between plant grade and normal river levels, it may be acceptable to use conservative simplified procedures to estimate flood levels at the site. Where calculated flood levels using simplified methods are at or above plant grade and using assumptions which cannot be demonstrated as conservative, it will be necessary to use unsteady flow methods to develop flood levels at the site. References 11 and 12 are acceptable methods; however, other programs would be acceptable with proper documentation and justification. Computations, coefficients, and methods used to establish the water level at the site for the most critical dam failures must be summarized. Coincident wind-generated wave activity should be considered in a manner similar to that discussed in SRP Section 2.4.3.

Appropriate sections of the guides described below are used by the staff to determine the acceptability of the applicant's data and analyses. Regulatory Guide 1.59, which incorporates ANSI N170, provides guidance for estimating the design basis for flooding considering the worst single phenomena and combination of less severe phenomena. Regulatory Guide 1.29 identifies the safety-related structures, systems, and components, and Regulatory Guide 1.102 describes acceptable flood protection to prevent the safety-related facilities from being adversely affected.

III. REVIEW PROCEDURES

The conservatism of the applicant's estimates of flood potential and low water levels from structure failures is judged against the criteria indicated in subsection II above. An analysis is performed using simplified, conservative procedures (such an instantaneous failure, coincident SPF flows, minimal flood wave attenuation, and extrapolated site discharge-rating curves). Techniques for such analyses are identified in standard hydraulic design references and text books, such as those listed in the reference section. If no potential flood problem exists, the staff safety evaluation report (SER) input is written accordingly. If the simplified analysis indicates a potential flooding problem, the analysis is repeated using a more refined technique which may include time rate of failure and hydrometeorologically compatible storm centerings. Detailed failure models, such as those of the Corps of Engineers and the Tennessee Valley Authority, are utilized to identify the outflows from various failure modes. Models of the Corps of Engineers or the Tennessee Valley Authority are used to identify the outflow characteristics and resultant water level at the site (Refs. 7, 11, 12, 16, 17 and 18). The staff will develop a position based on

the analyses performed; resolve, if possible, differences between the applicant's and staff's estimates; and write the SER input accordingly.

The above reviews are performed only when applicable to the site or site region. Some items of review may be done on a generic basis.

IV. EVALUATION FINDINGS

For construction permit (CP) reviews, the findings will summarize the applicant and staff evaluations in compliance with GDC 2, 10 CFR Part 100 and 10 CFR Part 100, Appendix A, of the design basis maximum and minimum water levels caused by potential dam failures. If the applicant's estimates are within acceptable margins (described in subsection II), staff concurrence in the applicant's estimates will be stated. If the applicant's estimates are not within acceptable margins, and if the plant may be adversely affected, a position requiring use of the staff bases will be stated. If no dam failure review was undertaken at the construction permit stage (of the scope described), this fact will be indicated.

For operating license (OL) reviews of cases for which detailed potential dam failure analyses were made during the CP review, the CP-stage conclusions will be referenced. In addition, any further review done to reaffirm the maximum or minimum water levels based on any new information will be described and the results and conclusions stated.

Sample statements for CP reviews follow:

> The staff concludes that the plant design flood elevation, at plant grade of 50 feet MSL, is acceptable and meets the requirements of General Design Criterion 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A, with respect to potential hazards due to dam failure floods. This conclusion is based on the following evaluation.
>
> The distance (more than 300 miles) to upstream reservoirs of appreciable size is such that the staff assessment leads to the conclusion that their arbitrarily assumed failure, under postulated combinations of floods and earthquakes of the severity discussed in Regulatory Guide 1.59, would not constitute a threat to the plant.
>
> Dam failure-caused "worst case" floods were evaluated by the applicant based upon failures with consideration of only the location and sizes of upstream impoundments, and not on inherent capability of such structures to resist earthquakes, volcanic activity and severe landslide-induced floods. The most severe flood of this kind was estimated based upon an assumed catastrophic failure of Dam A some 420 miles upstream. The peak flow at the site from such a flood was estimated to be 3,000,000 cfs. This flow is estimated to occur about two days after the dam failure and reach elevation 41 feet MSL, 9 feet below plant grade.
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> A volcanically-induced flood was assumed to cause a domino-type failure of the three dams on the tributary B River from a volcanic eruption of Mt. D. The evaluation indicated such an event could cause the second most severe artificial flood that would reach the site. This event was estimated to produce a peak flow at the site of 2,800,000 cfs and a water level of 39 feet MSL, 11 feet below plant grade.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 100, "Reactor Site Criteria."

3. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

4. "Flood Hydrograph Package," HEC-1, Corps of Engineers Hydrologic Engineering Center, Davis, California, October 1970.

5. "Water Surface Profiles," HEC-2, Corps of Engineers Hydrologic Engineering Center, Davis, California, February 1972.

6. "Reservoir System Operation for Flood Control," HEC-5, Corps of Engineers Hydrologic Engineering Center, Davis, California, May 1973.

7. "Routing of Floods Through River Channels," EM 1110-2-1408, Corps of Engineers, March 1960.

8. Hunter Rouse, ed., "Engineering Hydraulics," John Wiley & Sons, Inc., New York (1950).

9. Ven Te Chow, "Open-Channel Hydraulics," McGraw-Hill Book Co., New York (1959).

10. Ven Te Chow, ed., "Handbook of Applied Hydrology," McGraw-Hill Book Co., New York (1964).

11. J. M. Garrison, J. P. Granju, and J. T. Price, "Unsteady Flow Simulation in Rivers and Resorvoirs," Jour. Hydraulics Division, Proc. Am. Soc. of Civil Engineers, Vol. 95, No. HY5, pp. 1559-1576 (1969).

12. "Gradually Varied Unsteady Flow Profiles," 723-62-L2450, Corps of Engineers Hydrologic Engineering Center, Davis, California, March 1969.

13. R. A. Baltzer and C. Lai, "Computer Simulation of Unsteady Flows in Waterways," Hydraulics Division, Proc. Am. Soc. of Civil Engineers, Vol. 94, No. HY4, pp. 1083-1117 (1968).

14. J. J. Stoker, "Numerical Solution of Flood Prediction and River Regulation Problems," Reports I and II, New York Univ. (1953-54).

15. V. L. Streeter and E. B. Wylie, "Hydraulic Transients," McGraw Hill Book Co., New York, pp. 239-259 (1967).

16. W. A. Thomas, "A Method for Analyzing Effects of Dam Failures in Design Studies," Corps of Engineers Hydrologic Engineering Center, Davis California (for presentation at the ASCE Hydraulics Division Specialty Conference, Cornell University, August 1972).

17. "Flow Through a Breached Dam," Military Hydrology Bulletin No. 9, Corps of Engineers (1957).

18. "Floods Resulting From Suddenly Breached Dams, Conditions of High Resistance," Misc. Paper No. 2-374, Report 2, Corps of Engineers (1961).

19. Bureau of Reclamation, "Flood Routing," Chapter 6/0 in "Flood Hydrology," Part 6 in "Water Studies," Volume IV, U.S. Department of the Interior (1947).

20. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

21. Regulatory Guide 1.59, "Flood Design Basis for Nuclear Power Plants."

22. ANSI N170, "Standards for Determining Design Basis Flooding at Power Reactor Sites."

23. Regulatory Guide 1.29, "Seismic Design Classification."

24. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."

Figure 2.4.4-1

Standard Review Plan Section 2.4.4
Seismically - Induced Floods